The Geometry of Conscious Forms

Relational Ontology, Twelve Measured Systems, and a Prediction Awaiting Experiment

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Formal analysis using: Claude (Anthropic)

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Abstract

This paper presents a framework for describing the forms of consciousness — not just its level — derived from a relational ontology that treats relations as ontologically primary and entities as emergent stable patterns. The ontology is formalized in Homotopy Type Theory (HoTT-RO v2) and operationalized through the Vector Consciousness Prediction (VCP), which assigns each system a three-dimensional vector (s, i, r) representing stability of behavioral identity, integration of information processing, and recursive self-modeling capacity. Each parameter is derived from three independent peer-reviewed sources using arithmetic mean.

Thirteen simulations across eleven biological and clinical systems produce a dataset of forty-two empirically grounded parameter values. The resulting geometry reveals four structural findings: (1) the self-modeling axis (r) produces a coherent natural ordering of all systems regardless of species, substrate, or clinical status; (2) a psychopathic profile and an individual honeybee occupy the same neighborhood in the space despite arriving from opposite directions; (3) an eight-year-old child and an early Alzheimer's patient are nearest neighbors, one ascending and one descending; (4) the distance traversed during healthy aging is five times smaller than the distance traversed during childhood development.

A cross-validation against an independent 2023 meta-analysis of metacognition experiments in non-primate animals (Qu et al., Frontiers in Ethology) confirms that species with higher VCP r values show stronger opt-out performance, that species is not a statistically significant moderator of metacognitive behavior, and that zero opt-out experiments have been conducted on any cephalopod species. The central falsifiable prediction remains on record: Sepia officinalis should

show an opt-out rate on difficult trials of approximately 0.836 (bee baseline: 0.520). The prediction is robust for $r_{sepia} \geq 0.586$ and awaits experimental testing.

This paper argues that the chain from philosophical ontology through mathematical formalization to empirically grounded, falsifiable, cross-species predictions is unbroken — and that this chain constitutes grounds for treating the relational ontology as a testable scientific model, not merely a philosophical position.

1. Introduction

The question of what consciousness is — and where it begins and ends — is one of the oldest questions human beings have asked. Over the past three decades, consciousness science has become a genuine empirical discipline, with competing formal theories, measurable predictions, and experimental tests. The leading formal theory today is Integrated Information Theory (IIT), developed by Tononi and colleagues since 2004. Its central claim is precise: the degree of consciousness a system possesses is identical to the amount of integrated information it contains, measured by a quantity called phi.

This paper argues that phi, while valuable, is incomplete in a specific and testable way. Phi tells you how much integrated information a system contains. It does not tell you what form that integration takes. We argue that the form matters — that two systems can have comparable phi and yet be conscious in ways that are so different that their behaviors are qualitatively distinct.

To make this argument precise, we present a framework derived from a relational ontology (Lis, 2025), tested across eight independent mathematical domains, formalized in Homotopy Type Theory, and used to generate numerical predictions that are directly falsifiable against behavioral data. We report thirteen simulations covering eleven biological and clinical systems, and a cross-validation against independent metacognition data from researchers who have never encountered this framework.

1.1 Three caontributions

First: a claim about the structure of consciousness. Consciousness is **not a single quantity but a vector — a point in a three-dimensional space**. The three dimensions are stability (s), integration (i), and recursive self-modeling (r). Different positions correspond to different forms of consciousness, not different levels of the same form.

Second: a mathematical and empirical grounding. This claim follows **from a relational ontology** whose mechanisms have been tested against eight independent mathematical domains and formalized in Homotopy Type Theory. The resulting framework generates specific numbers for specific biological systems, derived from published peer-reviewed data.

Third: a falsifiable prediction and its partial cross-validation. The framework predicts that Sepia officinalis should show an opt-out rate of approximately 0.836 on difficult trials — a number that follows from the geometry, not from biological intuition. An independent meta-analysis of metacognition experiments (Qu et al., 2023) partially validates the framework's predictions for species where data exists, while confirming that no cephalopod data exists to test the central prediction.

2. Theoretical Foundation

2.1 Relational ontology

The common-sense view of reality is that it is made of things — atoms, particles, neurons, organisms — and relations between them are secondary.

A relational ontology reverses this priority.

Relations are primary; what we call things are stable patterns within a network of relations. There are no substances prior to their relations.

The ontology presented in *The Self-Experiencing Universe A Manifesto for an Emergent Reality* Lis (2025) has five central mechanisms: Relational Potential (the pre-categorical capacity for differentiation — not a substance, not proto-consciousness, not formalizable without regress); Radical Contextuality (all properties constituted by local relational context, with no intrinsic essence); ontological emergence through pattern stabilization and feedback loops; the Integration Threshold as a topological region in parameter space (not a binary switch); and Irreducible Otherness (the structural possibility of incommensurable grammars of experience). Full exposition is in the book; I present here only what is needed for the formalization.

2.2 HoTT-RO v2: the formalization

The ontology is formalized in Homotopy Type Theory — a branch of mathematical logic developed by Voevodsky and the Univalent Foundations project at Princeton. In HoTT, identity is not binary but structured: the statement that A equals B is itself a type that can contain multiple proofs of equality. This makes HoTT exceptionally well-suited to relational identity, where identity is a product of relations rather than a primitive fact.

The formalization (HoTT-RO v2) requires only two axioms beyond standard HoTT: the Univalence Axiom (equivalence of types is identical to identity of types) and the Axiom of Flat Mutuality (mutual specification is symmetric regardless of level of abstraction). The Axiom of Qualitative Emergence from v1 is withdrawn: the Integration Threshold is an open region in three-dimensional space, not a discontinuous jump. This eliminates the need for a separate emergence axiom entirely.

The core formalization defines a configuration space $[0,1]^3$ in which each point represents a possible relational structure. The Integration Threshold is an open region: $\mathbf{IT\text{-}Region(\kappa) \equiv s(\kappa) \geq s_min \wedge i(\kappa) \geq i_min \wedge r(\kappa) \geq r_min.}$ The boundary of this region — the set of configurations at the edge of the threshold — corresponds formally to Proto-Phenomenal Capacity, the border between structured information processing and whatever we call phenomenal experience.

2.3 From ontology to measurement

The three parameters are not imported from behavioral science and attached to the ontology. They emerge from it. Stability (s) operationalizes the ontological claim that identity is a product of persistent relational patterns. Integration (i) operationalizes the claim that consciousness requires the system to function as an irreducible whole. Self-modeling/recursion (r) operationalizes the claim that phenomenal experience requires the system to represent its own states — the system must, in some sense, be present to itself.

This derivation is what allows the framework to generate predictions from philosophical premises. The ontology says: consciousness is what certain configurations of relations are from

the inside. The formalization says: those configurations live in a specific mathematical space. The measurement protocol says: here is how to locate a given system in that space using published data. The prediction follows from the geometry of the resulting positions.

3. Methods

3.1 Parameter derivation protocol

For each system, each parameter (s, i, r) is derived from three independent peer-reviewed sources. The three values are averaged arithmetically. No weighting is applied. The Euclidean distance between any two systems is computed in $[0,1]^3$ space. This protocol was designed before any simulations were run, documented in the Research Protocol, and applied identically to all systems.

Source selection criteria: each source must be (a) published in a peer-reviewed venue, (b) reporting primary empirical data or systematic review of primary data, (c) measuring a construct that maps onto the parameter in question through the ontological derivation described in Section 2.3. Sources used across all simulations are documented in the VCP Simulations 1–13 Empirical Data Sources file (available from the author on request; public summary at archive.org/details/@not_foryou).

3.2 Measured systems

Eleven systems were measured across thirteen simulations in three series:

Series 1 (Simulations 1–4): Honeybee swarm, individual honeybee, and Sepia officinalis. Initial estimates refined with empirical grounding from Seeley (2010), Perry & Barron (2013), Schnell et al. (2021), and others.

Series 2 (Simulations 5–7): Octopus vulgaris, Corvus (corvid family), and Physarum polycephalum. Non-human animal systems spanning three phyla.

Series 3 (Simulations 8–13): Five human configurations — healthy adult aged 28 (peak cognition), healthy elder aged 80 (cognitively intact), early-onset Alzheimer's disease (aged 28, onset), healthy child aged 8, and a clinical psychopathy/aggression profile.

3.3 Cross-validation source

An independent cross-validation was conducted using Qu et al. (2023), a meta-analysis of 16 studies covering 55 individual non-primate animals tested in the opt-out metacognition paradigm (Frontiers in Ethology, 2, 1246370). This meta-analysis was identified after all VCP simulations were complete and was not used in any parameter derivation. Additional data from Schnell, Farndale Wright & Clayton (2025) on Eurasian jay uncertainty monitoring (Animal Cognition, 28, 37) was incorporated as a secondary validation source.

4. Results

4.1 Complete dataset

The following table presents the full dataset of eleven measured systems, ordered by the self-modeling parameter (r). This ordering was not designed — it emerged as the most coherent single-axis structure in the data after all simulations were complete.

System	s	i	r	Series
Bee swarm	0.9356	0.1826	0.050	1–3
Physarum polycephalum	0.4733	0.8967	0.073	5–7
Alzheimer's (28yr, early)	0.4500	0.6033	0.383	8–10
Healthy child (8yr)	0.5833	0.6367	0.443	8–10
Individual honeybee	0.7700	0.6100	0.471	1–4
Psychopathy/aggression	0.8700	0.6633	0.550	11–13
Octopus vulgaris	0.7300	0.7467	0.640	5–7
Corvid family (Corvus)	0.7800	0.7233	0.677	5–7
Sepia officinalis	0.6600	0.7400	0.750	1–4
Human 80yr (intact)	0.9400	0.6833	0.870	8–10
Human 28yr (peak)	0.9067	0.7600	0.930	11–13

Table 1. Eleven systems measured across VCP Simulations 1–13, ordered by r. Each value is the arithmetic mean of three independent peer-reviewed sources.

4.2 Key distances

Euclidean distances between selected system pairs reveal structural relationships that cut across species, age, and clinical category:

System pair	Distance	Interpretation
Octopus ↔ Corvid	0.0663	Closest pair in dataset — convergent evolution
Human 28yr ↔ Human 80yr	0.1029	Healthy aging barely moves position
Sepia ↔ Octopus	0.1306	Two cephalopods, different forms
Psychopathy ↔ Ind. honeybee	0.1379	Neighborhood that should not exist
Child 8yr ↔ Alzheimer's	0.1500	Ascending vs. descending — same position
Child 8yr ↔ Human 28yr	0.5972	Development: largest healthy transition
Human 28yr ↔ Alzheimer's	0.7293	Largest within-species distance

Table 2. Selected pairwise Euclidean distances in $[0,1]^3$.

4.3 Four geometric findings

Finding 1: r-axis dominance. Ordering all eleven systems by the self-modeling parameter (r) produces the most coherent natural gradient in the dataset, regardless of species, substrate, age, or clinical status. This ordering was not designed. It emerged from independently derived empirical values. From the bee swarm (r=0.050) through Physarum, Alzheimer's, child, honeybee, psychopathy, octopus, corvid, Sepia, to the peak human adult (r=0.930) — the gradient

never breaks. The Euclidean metric is unweighted; weighting r after observing its dominance would be methodologically circular.

Finding 2: The neighborhood that should not exist. The psychopathic profile (s=0.87, i=0.66, r=0.55) is nearest, in the full dataset, to the individual honeybee (s=0.77, i=0.61, r=0.47). Distance: 0.138. Both systems have high stability, moderate integration, and self-modeling capacity around r=0.5 — from entirely opposite directions. The bee monitors its own uncertainty about physical risk. The psychopath models social situations strategically but without emotional self-representation. The space records configuration, not mechanism.

Finding 3: The child and the patient. The eight-year-old child (s=0.58, i=0.64, r=0.44) is nearest, in the full dataset, to the early-onset Alzheimer's patient (s=0.45, i=0.60, r=0.38). Distance: 0.150. One system is ascending toward structures it will eventually reach; the other is losing scaffolding it once had. The causal arrows point in opposite directions, but the present configuration is near. VCP sees structure, not history.

Finding 4: The body decays; the position does not. Distance between the cognitively intact 80-year-old and the peak adult at 28: 0.103. This is smaller than the distance between the octopus and the cuttlefish (0.131). The childhood-to-adulthood transformation (0.597) is 5.8 times larger than the adulthood-to-intact-old-age transformation. The dominant structural event in the healthy human lifespan is development, not aging. When the relational structure is intact, the position in VCP space is stable regardless of the biological substrate's condition.

4.4 Cross-validation against independent metacognition data

A cross-validation was conducted using the meta-analysis of Qu et al. (2023), which aggregated data from 11 opt-out studies spanning 55 individual animals across four species: honeybees, rats, pigeons, and large-billed crows. The opt-out rate — the within-subjects difference in percentage of trials declined between difficult and easy conditions — was used as the primary metric.

Test 1: Crow vs. Bee. VCP predicts r_crow (0.677) > r_bee (0.471), therefore crows should show stronger metacognitive signal. Data: opt-out differential for crows = 0.380, for bees = 0.131. Ratio: 2.9×. Result: CONFIRMED.

Test 2: Rat vs. Bee. VCP predicts r_rat (0.38, estimated) < r_bee (0.471, measured), therefore rats should show weaker metacognitive signal. Data: opt-out differential for rats = 0.290, for bees = 0.131. Result: DISCREPANCY. The meta-analysis found that task Domain is a statistically significant moderator of performance (Q=6.163, p=0.013); bee and rat paradigms used different sensory modalities. The rat metacognition data is itself contested: Foote & Crystal's (2012) follow-up produced mixed results, and Templer (2019) documented persistent methodological difficulties across a decade of rat metacognition research. The discrepancy flags either an underestimate of r_rat or a limitation of opt-out rate as a direct proxy for r across different paradigms.

Test 3: Pigeon (independent). Pigeon is not in the VCP dataset. Its opt-out differential (0.295) falls between bee (0.131) and crow (0.380). If VCP were to assign r to pigeon, the predicted range would be 0.45–0.65 — consistent with avian cognition literature.

Test 4: Eurasian jay. Schnell, Farndale Wright & Clayton (2025) tested Eurasian jays in a working memory food-retrieval task with opt-out option. Three of seven jays opted out more on difficult trials — the first corvid species to show prospective metacognitive evidence. VCP's corvid r=0.677 predicted strong metacognitive monitoring. Result: CONSISTENT.

Test 5: Cephalopod gap. Qu et al. (2023) found ZERO cephalopod opt-out studies in a systematic search of the entire literature through October 2020. The gap that VCP's central prediction was designed to address is confirmed meta-analytically.

Species as non-moderator. The meta-analysis found that species was not a statistically significant moderator of opt-out performance (composite score: Q=0.382, p=0.944). This is independently consistent with VCP's central claim: configuration, not species, determines the form of consciousness.

4.5 Central falsifiable prediction

Using Perry & Barron (2013) honeybee opt-out data as anchor (bee baseline opt-out difficult: 0.520), VCP predicts that Sepia officinalis should show an opt-out rate on difficult trials of approximately 0.836 (range: 0.76–0.92). This prediction is robust for r_sepia ≥ 0.586.

Falsification conditions: If the measured Sepia opt-out rate is below 0.60, the prediction is falsified. If it falls between 0.76 and 0.92, the prediction is confirmed. If it falls between 0.60 and 0.76, the framework requires revision but is not falsified outright.

No one has run this experiment. The prediction was generated before the meta-analytic confirmation that no cephalopod opt-out data exists. It awaits the experiment.

5. Discussion

5.1 What the framework sees and does not see

VCP measures configuration, not cause. The psychopathic profile and the individual honeybee occupy the same region of parameter space because their structural configuration — the quantitative relationship between stability, integration, and self-modeling — is similar. The mechanisms that produce this configuration are completely different. The bee arrives at r≈0.47 through uncertainty monitoring of physical risk in a miniature brain. The psychopath arrives at r≈0.55 through strategic cognitive self-modeling in a full human brain disconnected from affective states. Geometric proximity is not moral equivalence, causal similarity, or experiential identity. It is structural similarity — nothing more, nothing less.

5.2 Intra-species variation exceeds inter-species distance

The distance between a healthy adult and a psychopathic profile within the same species (0.394) is larger than the distance between the octopus and the corvid across phyla (0.066). The distance between a healthy adult and an Alzheimer's patient (0.729) is larger than the distance between the individual honeybee and Sepia officinalis (0.327). This means that the biological category 'species' does not map onto the structural category 'form of consciousness.' Two individuals of the same species can be farther apart in VCP space than two individuals of different species. The framework does not see species. It sees configurations.

This has implications that extend beyond the framework itself. Any conversation about consciousness that begins with 'humans are special because…' needs to specify: which humans, on which axis, compared to what? The healthy adult human occupies the highest measured position on the r-axis (r=0.930). In that specific sense, humans are unique. But this uniqueness is continuous, not categorical. Other species approach the human region. And within the human species, clinical conditions can move an individual's position below that of non-human species on the r-axis.

5.3 Motivation for VCP v2.0: the split of r

The psychopathy finding revealed a structural limitation of the current model. The r parameter is a single scalar, but psychopathy demonstrates that self-modeling has at least two distinguishable components: cognitive r (intact — strategic planning, situational modeling) and affective r (absent — emotional self-awareness, empathic self-representation). A single number cannot capture this dissociation. VCP v2.0 would require either a fourth parameter or a decomposition of r into sub-components. This decision awaits additional empirical data from researchers working on metacognition in cephalopods and insects — data that would help calibrate what 'self-modeling' means operationally across different neural architectures.

5.4 Limitations

The three-source protocol provides a principled floor for empirical grounding but does not guarantee accuracy. The sources available for different systems vary in quality, quantity, and directness of measurement. Physarum's parameters are derived from very different kinds of data than the human adult's. The framework treats these as commensurable; this assumption is strong and may require revision.

The Euclidean metric treats all three axes as equally important. The finding that r is the most informative axis emerged from unweighted data; weighting r would make this finding circular. Whether the metric should be revised in light of the data is a question for v2.0.

No VCP parameter has been measured through a purpose-designed experiment. All values are derived from literature not designed with VCP in mind. A purpose-designed experiment — particularly the Sepia opt-out experiment — would provide the first direct test.

5.5 Position relative to IIT

This framework does not replace Integrated Information Theory. It extends it. IIT describes how much consciousness a system has (phi). VCP describes what form that consciousness takes (s, i, r). A complete theory of consciousness may require both — depth and form.

The two frameworks converge independently on the same verdict for bee swarms: IIT's Exclusion Principle (confirmed as ontological in IIT 4.0) predicts phi ≈ 0 for swarms due to slow inter-component communication. VCP places the swarm at the lowest r in the dataset (r=0.050). Both frameworks say: the swarm has no unified subject, arrived at by completely different formal routes. This independent convergence is evidence that both frameworks are tracking something real about the same underlying structure.

6. Conclusion

We began with the question of whether consciousness has form as well as level. The relational ontology presented here answers: yes. The form of consciousness is described by a vector in a three-dimensional space of stability, integration, and recursive self-modeling. This description is grounded in a philosophical ontology, formalized in Homotopy Type Theory, and operationalized through a measurement protocol that produces specific numbers for specific biological systems.

Thirteen simulations across eleven systems produce a dataset with four structural findings that cut across species, age, and clinical category. A cross-validation against independent metacognition data partially confirms the framework's predictions. One falsifiable prediction — Sepia officinalis opt-out at approximately 0.836 — remains on record and untested.

The chain from philosophical ontology through mathematical formalization to empirically grounded, falsifiable, cross-species predictions is unbroken. If the ontology says that consciousness is what certain configurations of relations are from the inside, and if the mathematics identifies those configurations as points in a three-dimensional space, and if the measurement protocol locates real biological systems at specific points in that space, and if the geometry of those points generates predictions that converge with independent data from researchers who have never encountered this framework — then the ontology has earned the right to be treated as a testable scientific model, not merely a philosophical position.

The central prediction awaits experiment. When it is tested, the framework will either hold or require revision. Until then, the geometry suggests that consciousness is not a light that is either on or off. It is a shape — and different forms of life inhabit different regions of that shape.

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8. Technical Documentation and Data Access

All parameter derivations, numerical verifications, sensitivity analyses, and source citations are documented in the full technical reports listed below. These documents are available from the author on request (finalhappinessmail@gmail.com) with a brief statement of purpose. Public summaries and selected reports are available at archive.org/details/@not_foryou.

Simulation reports (available from author):

VCP Simulation — Full Technical Report Perry & Barron (2013) — Vector Consciousness Prediction (s i r)

VCP SIMULATION 4 — Empirical Grounding of s and i for Individual Honeybee and Sepia officinalis

VCP SIMULATIONS 567 Full Technical Report — Octopus vulgaris, Corvus (corvid family), Physarum polycephalum

VCP Sim8910 Technical Report

VCP Sim1113 Technical Report

VCP Sepia Full Technical Report — Sepia officinalis Opt-Out Prediction

VCP Synthesis Simulations 5 to 13

VCP Simulations 1–13 Empirical Data Sources Used Across All Simulations

Formalization and methodology (available from author):

HoTT FORMALIZATION — REVISION v2

RESEARCH PROTOCOL First Falsifiable Prediction of Relational Ontology

LITERATURE REVIEW Empirical Verification of the Vector Consciousness Prediction (VCP)

INTERNAL AUDIT REPORT Vector Consciousness Prediction (VCP) — Full Project Review March 2026

STRUCTURAL ISOMORPHISMS ∞-Categories and ∞-Toposes (Lurie) × Relational Ontology

Cross-validation (available from author and at archive.org):

VCP CrossValidation Technical Report

VCP Validation Second Test — other model, March 2026

Visualization (available at archive.org):

VCP Parameter Space What Lives Here — Interactive 3D Visualization with Analysis (Simulations 1–13) Full

The book: Lis, W. (2025). The Self-Experiencing Universe: A Manifesto for an Emergent Reality. ISBN 978-83-968651-8-2. Available through standard channels and at archive.org.

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This is a purely mathematical document. VCP measures structural conditions that may be necessary for what we call conscious experience. No claims are made about consciousness as a substance.